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ABSTRACT

This paper describes three experiments which demonstrated the presence of binaural perception abilities (the ability to use both ears) in 4-month-old but not in 2-month-old infants. All of the experiments employed a visual fixation habituation-dishabituation paradigm in which infants were given a series of visual fixation trials while binaural stimuli were presented through earphones. The first experiment tested the perception of interaural time differences. There was a significant increase in looking time on the first dishabituation trial for the 4-month-old infants. The second experiment tested the perception of interaural intensity differences. When the tones to the two ears were exchanged on the dishabituation trials, there was again a significant increase in fixation time for the 4-month-olds. The third experiment tested for binaural release from masking. Identical noise was presented to each ear during trials 1-7. A low intensity in-phase tone was added during trials 6 and 7. The same tone was presented out of phase on trials 8-10. The 4-month-olds showed no change in fixation during trials 6 and 7, but showed a significant increase on trial 8. The results of the experiments indicate that infants as young as 4 months of age are able to utilize binaural information in much the same way as adults. (Author/BD)

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Binaural Perception in Young Infants

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PS 009476

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The research that I am going to report demonstrates that infants as young as 4 months of age are able to perceive and utilize binaural information. There are two basic abilities which require the use of two ears. The first ability is "sound localization" which enables a person to turn towards the source of a sound. The second ability, commonly called the "cocktail party effect," helps us to pay attention to a sound in a noisy environment. Both of these abilities require the analysis of intensity and arrival time differences between the two ears. Since we know almost nothing about the ontogeny of binaural processing in infants, the following experiments were designed to ask some basic questions about the development of these abilities.

The first experiment was designed to determine if two and four month old infants are able to perceive and utilize interaural arrival time differences for sound localization. We had no apriori reason for selecting this age group since there was little data to suggest an age at which this ability might appear. The paradigm which I chose, however, was very similar to the paradigm which Horowitz and her colleagues (Horowitz, 1974) had used successfully with infants of this age so it seemed to be an appropriate starting point.

The experiment consisted of 20 visual fixation trials of 8 seconds each. The visual fixation targets were two 8 by 8 checkerboards located about 20 cm apart and approximately 35 cm in front of the infant's face. A fixation light was located between the two targets. Each trial started out with the flashing fixation light. When the observer noted that the infant was looking directly at the fixation light, the trial was initiated by turning off the fixation light and turning on the checkerboard. At

the same time the infant heard a 400 HZ sine wave tone presented through the earphones with the tone to one of the ears delayed by 300 microseconds. For adults a sound located completely to one side of the head arrives at one ear about 600 microseconds before it arrives at the other ear. Since an infant's head is somewhat smaller, the arrival time differences would be somewhat less, probably around 400 microseconds. Although the acoustic energy is exactly the same in both of the ears, most adults report that the sound is louder in the ear that hears the sound first. For the first 5 trials no sound was presented during the fixation trials. This was to ascertain if the infant had any initial preference for turning right or left so that this bias could be partialed out in the analysis. Most infants had a preference for turning to the right. For trials 6 through 15 the tone was presented during the fixation trials with the sound delayed to one of the ears. On trials 16 through 20 the signals to the two ears were interchanged so that the sound seemed to be coming from the opposite side. During the trials the visual fixation to the two targets was noted by an observer. It was expected that the infant would tend to look toward the apparent source of the sound if they were able to perceive and use arrival time cues.

The first slide shows the directional looking data for the 4 month olds. The upper graph is arranged so that if localization had occurred,

SLIDE 1

the line would have been at the middle during the first five trials since there was no sound being presented during these trials. The line

would then have been at the top of the graph for trials 6 through 15 and at the bottom of the graph for trials 16 through 20. In the lower graph the total looking time to the initial correct side was simply subtracted from the total looking time to the incorrect side. As you can see, there was no evidence for localization in the 4 month olds. The two month olds produced virtually the same data.

When we added the total right and left looking times together, we found that the four month olds were showing habituation during the experiment and dishabituation on the test trials when the apparent source of the sound changed sides. The results for the two and four month olds is shown in the next slide. The difference in looking time

SLIDE 2

between trials 15 and 16 is significant at the .05 level. Although the two month olds showed a slight tendency toward habituation and dishabituation, none of the trends approached statistical significance. It is clear that the four month olds were able to detect the change in interaural arrival time but since the two month old infants did not habituate, we have no way of knowing whether they could detect the change.

The second experiment was identical to the first except that the tone presented to the ears differed in intensity by 16 Db. The data for this experiment was very similar to the first experiment since the infants showed no localization, but the four month olds did show habituation during the initial trials and dishabituation on the test trials.

It is possible that infants of this age simply cannot localize,and as a consequence, localization may be an inappropriate dependent variable to test for binaural perception in infants. There is some dispute about

the actual age at which sound localization first appears. A report by Wertheimer (1961) of sound localization in one newborn is commonly cited, but there is no other evidence that sound localization occurs this early. However, an attempt to replicate Wertheimer's study by McGurk, Turnure, and Creighton (1977) failed to find any localization in newborns. A report by Chun, Pawsat, and Forster (1960) and both the Bailey and Gesell developmental scales indicate that reliable sound localization does not normally appear before about 5 months of age.

It is also possible that the stimuli are not appropriate for localization. Aside from the fact that infants rarely, if ever, hear pure sine wave tones in the normal environment, there are a number of other factors which make the stimuli rather unusual. Normally, arrival time and intensity cues are confounded since one does not usually hear a sound which has the same intensity in both ears but has different arrival times. It may be that receiving conflicting cues disrupts what localization abilities that the infant does have. Also, receiving the sound through earphones is rather unusual since rotation of the head does not produce any interaural changes. In adults head rotation while wearing earphones produces the illusion that the sound is located inside the head. The infant might not expect to localize a sound which has qualities which it has never experienced. Some adults, in fact, have some difficulty detecting changes in interaural delays with pure tones.

There are a couple of possible explanations why infants would be able to detect interaural differences but be unable to localize. It could be that the four month old infants in my experiment had just

acquired the ability to detect these cues but had not yet learned to localize. This explanation seems unlikely since a study by Leventhal and Lipsitt (1964) has shown that neonates will show dishabituation when the location of a sound source is changed indicating that the infant can detect interaural differences earlier than 4 months of age. Also it has been demonstrated by Papousek (1961) that infants of this age can be operantly conditioned to turn their heads. Since the response can be conditioned and the stimulus can be detected, it remains somewhat of a puzzle why infants take so long to develop sound localization. It seems to me that infants less than 5 or so months of age must have an inability to associate spacial relationships between the visual and auditory modes. I am now in the process of carrying out experiments to determine more unambigously the age at which infants can first detect binaural cues and to narrow down the possible reasons for the lack of sound localization before about 5 months of age.

In the third experiment, I tested for the "cocktail party effect" in infants by testing for binaural release from masking. Unfortunately I have only pilot data to report for this experiment since I had to discontinue the experiment when I moved to a new location. Since the first two experiments indicated that visual fixation might be a good dependent variable for the study of binaural processing, I used a modified version of this paradigm to test for binaural release from masking. One of the simplest ways of demonstrating binaural release from masking in adults is to present identical noise to both ears and then add a signal to the noise. The subject is then asked to reduce the level of the signal until he can no longer hear it. If the tone to

one of the ears is inverted so that the signal is now 180 degrees out of phase in the two ears, the masking is then "released" so that the signal is then apparent in the noise. This experiment consisted of 12 visual fixation trials. Each trial was preceded by a flashing light as in the first two experiments. When the infant fixated on the light, the light was turned off and a checkerboard stimulus was turned on. During the entire experiment, identical, bandwidth limited, noise was presented to each ear through the earphones. When the infant had looked at the checkerboard for at least one second and looked away for at least a half a second, the trial was terminated and the flashing light was turned back on. The stimulus presentation sequence is shown in the next slide. During trials 1 through 7 only the white noise was presented.

SLIDE 3

During trials 8 and 9 an in-phase 400 HZ tone was added to the noise. The level of this tone was adjusted so that most adult listeners said that they could not hear the tone in the noise. On trials 10 through 12 the sine wave tone was inverted in one of the ears. Nearly all adults report that they can hear the tone in the noise under these conditions. We have tested a few 2 month olds, but unfortunately four of the five two months olds fell asleep during the first couple of trials. They do not look away from the stimulus and apparently the noise lulls them to sleep. The next slide shows the data for the

SLIDE 4

first three four-month-old subjects and so far the results look quite encouraging. As you can see, the fixation times did decrease during the first trials. When the in-phase tone was added to the noise, there was no increase in fixation times as one would expect since adults

cannot hear the tones under these conditions. On test trials 10 through 12 there was a very noticeable increase in fixation time indicating that the infants could then detect the tone.

The results of these experiments taken together indicate that infants as young as four months of age are able to utilize binaural information in much the same way as adults. Results from other experiments suggest that although they are able to detect binaural information, they are not yet capable of using it to localize the source of a sound. Further experiments are needed to determine the age at which infants first acquire these abilities and to determine the reason infants of less than 5 months of age cannot localize sound.

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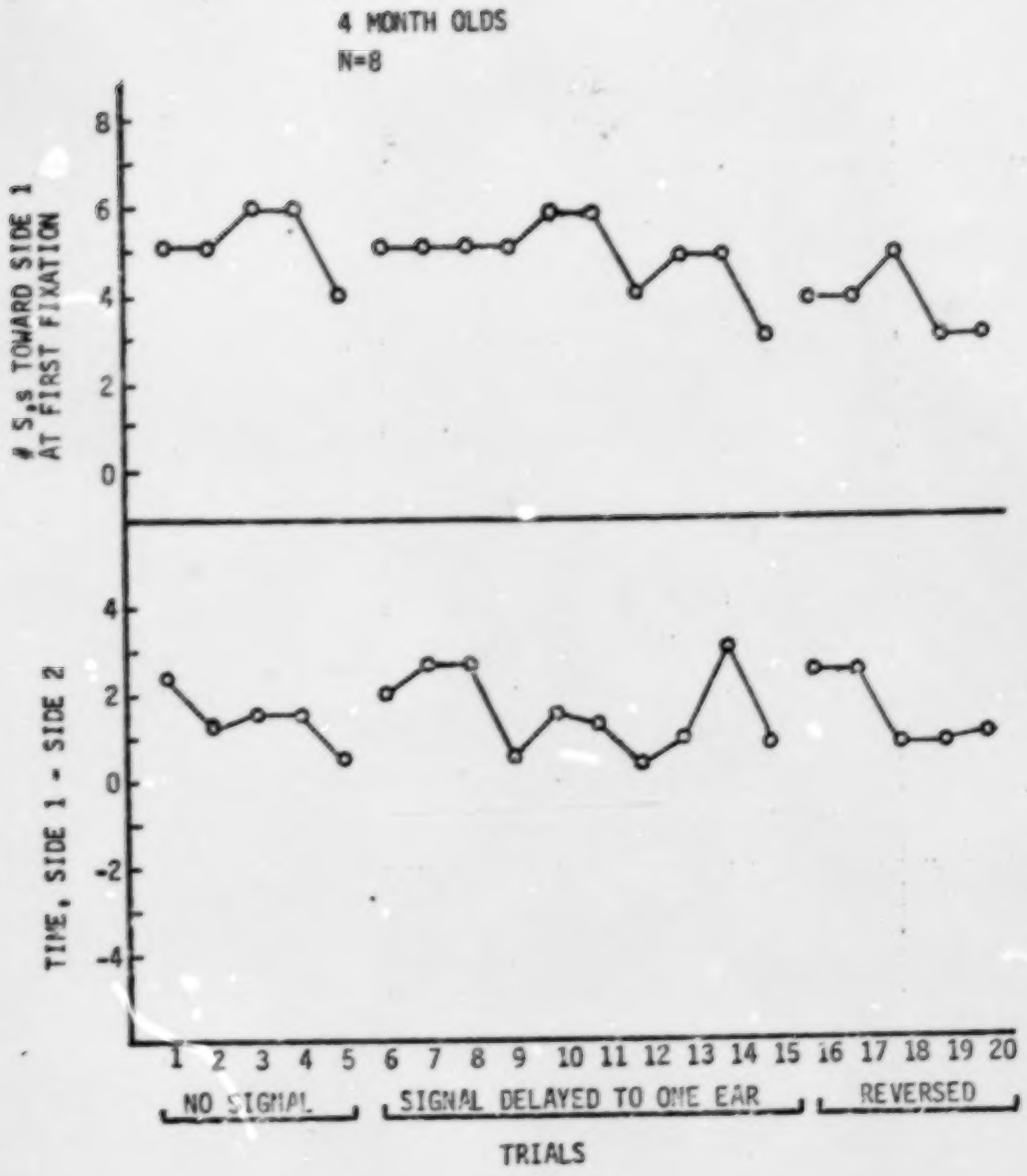
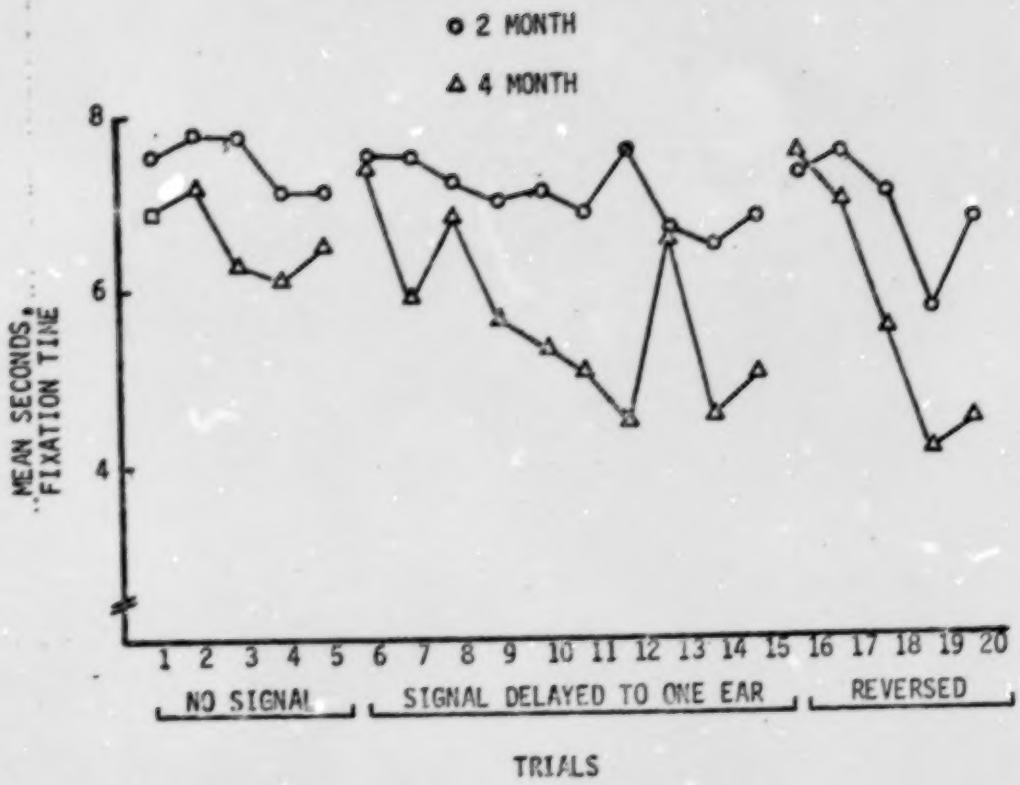

4 MONTH OLDS
N=8
# S,s TOWARD SIDE 1
AT FIRST FIXATION
8
6
4
2
0
TIME, SIDE 1 - SIDE 2
4
2
0
-2
-4
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
NO SIGNAL
SIGNAL DELAYED TO ONE EAR
REVERSED
TRIALS

SLIDE 1


2 MONTH
4 MONTH
MEAN SECONDS FIXATION TIME
8
6
4
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
NO SIGNAL
SIGNAL DELAYED TO ONE EAR
REVERSED
TRIALS

SLIDE 2

BINAURAL MASKING

TRIALS 1-7

NOISE

NOISE

TRIALS 8-9

NOISE + TONE

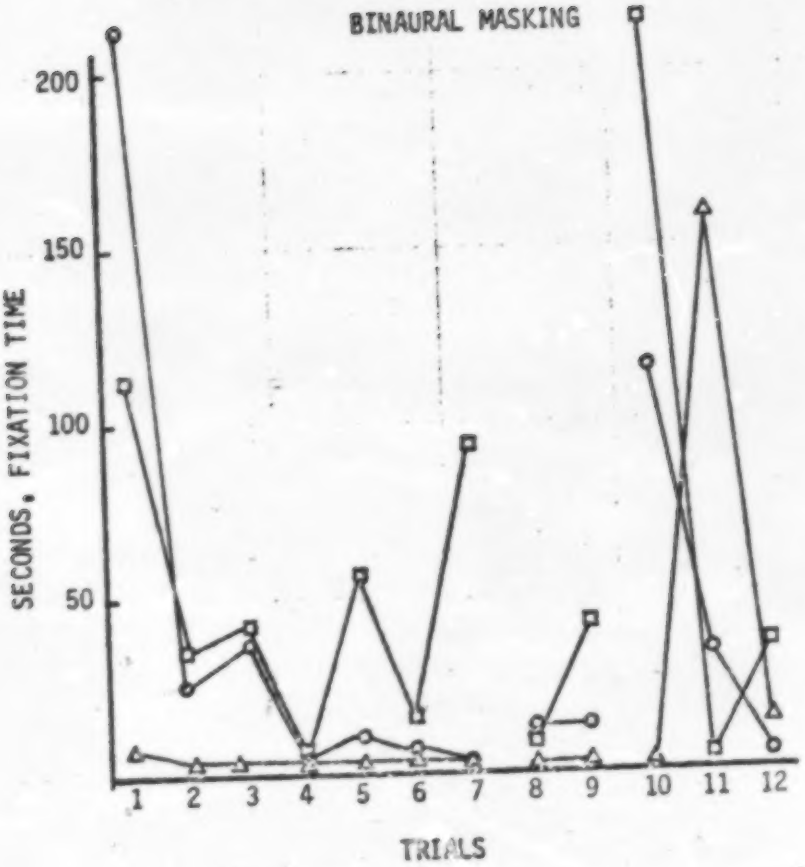
NOISE + TONE

TRIALS 10-12

NOISE + TONE

NOISE + $\overline{\text{TONE}}$

SLIDE 3


BINAURAL MASKING
200
150
100
50
SECONDS, FIXATION TIME
1
2
3
4
5
6
7
8
9
10
11
12
TRIALS

SLIDE 4